

Lecture 23

# **While Loops**

# Announcements for This Lecture

---

## Prelim 2

- **Prelim, Nov. 17 at 7:30**
  - **A-L** in Bailey 101
  - **M-Z** in Uris G01
- **Material up to Nov. 8**
  - Recursion + Loops + Classes
  - Review session this Sun
- **Conflict with Prelim?**
  - Last call for CMS entry

## Assignments

- A6 due on **Monday**
  - Task 1 & 2 should be done
  - Task 3 this weekend
- A7 will be last assignment
  - Will be posted **Tuesday**

## Optional Videos

- **Lessons 26** for **today**
- **Lesson 27** for next time

# Recall: The For-Loop

---

```
# Create local var x
```

```
x = seqn[0]
```

```
print(x)
```

```
x = seqn[1]
```

```
print(x)
```

```
...
```

```
x = seqn[len(seqn)-1]
```

```
print(x)
```

Not valid  
Python

```
# Write as a for-loop
```

```
for x in seqn:
```

```
    print(x)
```

## Key Concepts

---

- **iterable:** seqn
- **loop variable:** x
- **body:** print(x)

# Important Concept in CS: Doing Things Repeatedly

## 1. Process each item in a sequence

- Compute aggregate statistics for a sequence of numbers, such as the mean, median, standard deviation
- Send everyone in a Facebook group an appointment time

```
for x in sequence:  
    process x
```

## 2. Perform $n$ trials or get $n$ samples.

- A4: draw a triangle six times to make a hexagon
- Run a protein-folding simulation

```
for x in range(n):  
    do next thing
```

## 3. Do something an unknown number of times

- CUAUV team, vehicle keeps moving until reached its goal

????



# Beyond Sequences: The while-loop

**while** *<condition>*:

statement 1

...

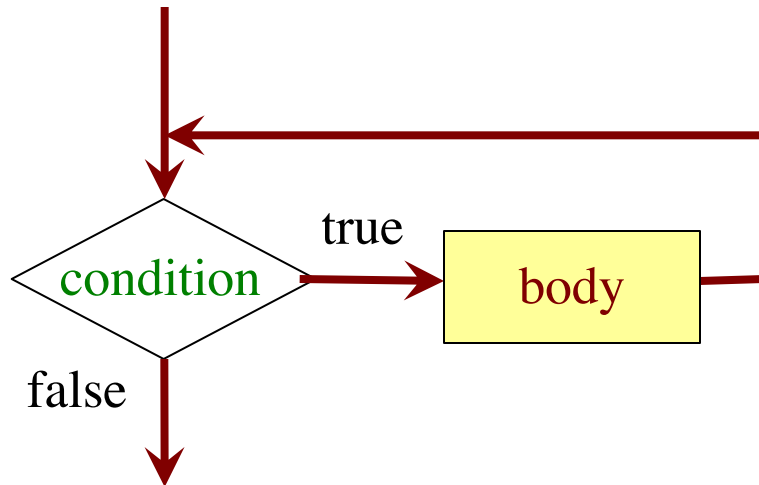
statement n

**loop  
condition**

**loop  
body**

## Vs For-Loop

- Broader notion of loop
  - You define “more to do”
  - Not limited sequences
- Must manage loop var
  - You create it before loop
  - You update it inside loop
  - For-loop automated it
- Trickier to get right



# while Versus for

## For-Loop

```
def sum_squares(n):  
    """Rets: sum of squares  
    Prec: n is int > 0"""  
    total = 0  
    for x in range(n):  
        total = total + x*x
```

Must remember  
to increment

## While-Loop

```
def sum_squares(n):  
    """Rets: sum of squares  
    Prec: n is int > 0"""  
    total = 0  
    x = 0  
    while x < n:  
        total = total + x*x  
        x = x+1
```

# The Problem with While-Loops

---

- Infinite loops are possible
  - Forget to update a loop variable
  - Incorrectly write the boolean expression
- Will hang your program
  - Must type control-C to abort/quit
- But detecting problems is not easy
  - Sometimes your code is just slow
  - Scientific computations can take hours
- **Solution:** Traces

# Tracing While-Loops

```
print('Before while')
```

```
total = 0
```

```
x = 0
```

```
while x < n:
```

```
    print('Start loop '+str(x))
```

```
    total = total + x*x
```

```
    x = x + 1
```

```
    print('End loop ')
```

```
print('After while')
```

Important

Important

Output:

Before while

Start loop 0

End loop

Start loop 1

End loop

Start loop 2

End loop

After while



# How to Design While-Loops

---

- Many of the same rules from for-loops
  - Often have an **accumulator variable**
  - Loop body adds to this accumulator
- Differences are loop variable and iterable
  - Typically **do not have iterable**
- Breaks up into three **design patterns**
  1. Replacement to range()
  2. Explicit goal condition
  3. Boolean tracking variable

# While Loops and Lists

---

## For-Loop

---

```
def increment_for(seq):  
    """Increments each  
    element of seq list  
    Prec: seq contains ints"""  
    for k in range(len(seq)):  
        seq[k] = seq[k]+1
```

Must still remember  
to increment

## While-Loop

---

```
def increment_while(seq):  
    """Increments each  
    element of seq list  
    Prec: seq contains ints"""  
    k = 0  
    while k < len(seq):  
        seq[k] = seq[k]+1  
        k = k + 1
```

# Using the Goal as a Condition

---

```
def prompt(prompt,valid):
```

```
    """Returns: the choice from a given prompt.
```

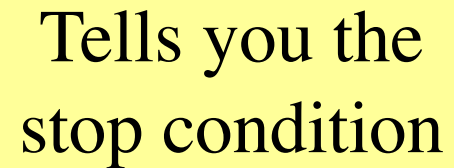
```
    This function asks the user a question, and waits for a response. It checks if the response is valid against a list of acceptable answers.
```

```
    If it is not valid, it asks the question again. Otherwise, it returns the player's answer.
```

```
    Precondition: prompt is a string
```

```
    Precondition: valid is a tuple of strings"""
```

```
    pass # Stub to be implemented
```



Tells you the stop condition

# Using the Goal as a Condition

---

```
def prompt(prompt,valid):
```

```
    """Returns: the choice from a given prompt.
```

```
    Preconditions: prompt is a string, valid is a tuple of strings"""
```

```
    response = input(prompt)
```

```
    # Continue to ask while the response is not valid.
```

```
    while not (response in valid):
```

```
        print('Invalid response. Answer must be one of ')+str(valid)
```

```
        response = input(prompt)
```

```
    return response
```

# Using a Boolean Variable

---

```
def roll_past(goal):
```

```
    """Returns: The score from rolling a die until passing goal.
```

```
    This function starts with a score of 0, and rolls a die, adding the
    result to the score. Once the score passes goal, it stops and
    returns the result as the final score.
```

```
    If the function ever rolls a 1, it stops and the score is 0.
```

```
    Preconditions: goal is an int > 0"""
```

```
    pass # Stub to be implemented
```

Condition is  
too complicated

**Introduce a boolean variable.  
Use it to track condition.**

# Using a Boolean Variable

```
def roll_past(goal):
```

```
    """Returns: The score from rolling a die until passing goal."""
```

```
    loop = True # Keep looping until this is false
```

```
    score = 0
```

```
    while loop:
```

```
        roll = random.randint(1,6)
```

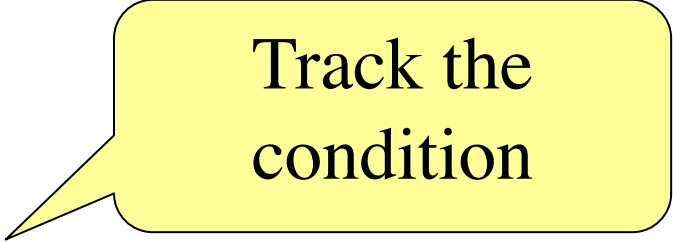
```
        if roll == 1:
```

```
            | score = 0; loop = False
```

```
        else:
```

```
            | score = score + roll; loop = score < goal
```

```
    return score
```



Track the  
condition

# Advantages of while vs for

---

```
# table of squares to N
seq = []
n = floor(sqrt(N)) + 1
for k in range(n):
    seq.append(k*k)
```

```
# table of squares to N
seq = []
k = 0
while k*k < N:
    seq.append(k*k)
    k = k+1
```

A for-loop requires that you know where to stop the loop **ahead of time**

A while loop can use complex expressions to check if the loop is done

# Advantages of while vs for

---

Fibonacci numbers:

$$F_0 = 1$$

$$F_1 = 1$$

$$F_n = F_{n-1} + F_{n-2}$$

# Table of n Fibonacci nums

```
fib = [1, 1]
```

```
for k in range(2,n):
```

```
    fib.append(fib[-1] + fib[-2])
```

Sometimes you do not use  
the loop variable at all

# Table of n Fibonacci nums

```
fib = [1, 1]
```

```
while len(fib) < n:
```

```
    fib.append(fib[-1] + fib[-2])
```

Do not need to have a loop  
variable if you don't need one



# Difficulties with while

Be careful when you **modify** the loop variable

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    i = 0  
    while i < len(lst):  
        # no 3's in lst[0..i-1]  
        if lst[i] == 3:  
            del lst[i]  
            i = i+1
```

```
>>> a = [3, 3, 2]  
>>> rem3(a)  
>>> a
```

A: [2]  
B: [3]  
C: [3,2]  
D: []  
E: something else

# Difficulties with while

Be careful when you **modify** the loop variable

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    i = 0  
    while i < len(lst):  
        # no 3's in lst[0..i-1]  
        if lst[i] == 3:  
            del lst[i]  
            i = i+1
```

```
>>> a = [3, 3, 2]  
>>> rem3(a)  
>>> a
```

A: [2]  
B: [3]  
C: [3,2] **Correct**  
D: []  
E: something else

# Difficulties with while

Be careful when you **modify** the loop variable

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    i = 0  
    while i < len(lst):  
        # no 3's in lst[0..i-1]  
        if lst[i] == 3:  
            del lst[i]  
        else:  
            i = i+1
```

Stopping  
point keeps  
changing

```
def rem3(lst):  
    """Remove all 3's from lst"""  
    while 3 in lst:  
        lst.remove(3)
```

The stopping condition is not  
a numerical counter this time.  
Simplifies code a lot.

# Application: Convergence

---

- How to implement this function?

```
def sqrt(c):
```

```
    """Returns the square root of c"""
```

- Consider the polynomial  $f(x) = x^2 - c$ 
  - Value `sqrt(c)` is a *root* of this polynomial
- Suggests a use for **Newton's Method**
  - **Start with a guess** at the answer
  - Use calculus formula to improve guess

## Example: Sqrt(2)

---

- Actual answer: 1.414235624
- $x_{n+1} = x_n/2 + c/2x_n$
- $x_0 = 1$  # Rough guess of sqrt(2)
- $x_1 = 0.5 + 1 = 1.5$
- $x_2 = 0.75 + 2/3 = 1.41666$
- $x_3 = 0.7083 + 2/2.833 = 1.41425$

# When Do We Stop?

---

- We don't know the  $\text{sqrt}(c)$ 
  - This was thing we wanted to compute!
  - So we cannot tell how far off we are
  - But we do know  $\text{sqrt}(c)^2 = c$
- So square approximation and compare
  - `while`  $x*x$  is not close enough to  $c$
  - `while`  $\text{abs}(x*x - c) > \text{threshold}$

# When Do We Stop?

---

- We don't know the  $\text{sqrt}(c)$ 
  - This was thing we wanted to compute!
  - So we cannot tell how far off we are
  - But we do know  $\text{sqrt}(c)^2 = c$
- So square approximation and compare

**While-loop computes until  
the answer **converges****

# The Final Result

---

```
def sqrt(c,err=1e-6):  
    """Returns: sqrt of c with given margin of error.  
  
    Preconditions: c and err are numbers > 0"""  
    x = c/2.0  
  
    while abs(x*x-c) > err:  
        # Get  $x_{n+1}$  from  $x_n$   
        x = x/2.0+c/(2.0*x)  
  
    return x
```



# Using while-loops Instead of for-loops

---

## Advantages

---

- Better for **modifying data**
  - More natural than range
  - Works better with deletion
- Better for **convergent tasks**
  - Loop until calculation done
  - Exact steps are unknown
- Easier to **stop early**
  - Just set loop var to False

## Disadvantages

---

- Performance is **slower**
  - Python optimizes for-loops
  - Cannot optimize while
- **Infinite loops** more likely
  - Easy to forget loop vars
  - Or get stop condition wrong
- **Debugging** is harder
  - Will see why in later lectures

# Optional Exercise

# The Game of Pig: A Random Game

---

- Play progresses clockwise
- On your turn, throw the die:
  - If roll 1: lose turn, score zero
  - Anything else: add it to score
    - Can also roll again (and lose)
    - If stop, score is “banked”
- First person to 100 wins



# The Game of Pig: A Random Game

---

- Play progresses clockwise
- On your turn, throw the die:

- If roll 1: lose

- Anyt

**Easy to write without classes**

- Can also roll again (and lose)
- If stop, score is “banked”

- First person to 100 wins



# Designing an AI for Opponent is Easy

---

# Throws	Survial	Expected Gain	Expected Value
1	83%	3.33	3.33
2	69%	2.78	6.11
3	58%	2.32	8.43
4	48%	1.92	10.35
5	40%	1.61	11.96
6	33%	1.34	13.30
7	28%	1.12	14.42
8	23%	.93	15.35
9	19%	.77	16.12
10	16%	.65	16.77
...	...	...	...
50	0.01%	0.0004	19.998

# Designing an AI for Opponent is Easy

# Throws	Survial	Expected Gain	Expected Value
1	83%	3.33	3.33
2	69%	2.78	6.11
3	58%	2.32	8.43
4	48%	1.92	10.35
5	40%	1.61	11.96
6	33%	1.34	13.30
7	28%	1.12	14.42
8	23%	.93	15.35
9	19%		16.12
10	16%		16.77
...	...	...	...
50	0.01%	0.0004	19.998

**Strategy:**  
Bank at 20

# The Primary Function

---

```
def play(target):  
    """Plays a single game of Pig to target score.  
  
    Precondition: target is an int > 0"""  
    # Initialize the scores  
    # while no one has reached the target  
        # Play a round for the player  
        # If the player did not reach the target  
            # Play a round for the opponent  
    # Display the results
```

# The Player Round

---

```
def player_turn():
```

```
    """ Runs a single turn for the player. """
```

```
    # while the player has not stopped
```

```
        # Roll the die
```

```
        # If is a 1
```

```
            # Set score to 0 and stop the turn
```

```
        # else
```

```
            # Add the to the score
```

```
            # Ask the player whether to continue
```

```
    # Return the score
```



Prompt helper



# The Opponent Round

---

```
def roll_past(goal):
```

```
    """Returns: The score from rolling a die until passing goal."""
```

```
    loop = True # Keep looping until this is false
```

```
    score = 0
```

```
    while loop:
```

```
        roll = random.randint(1,6)
```

```
        if roll == 1:
```

```
            | score = 0; loop = False
```

```
        else:
```

```
            | score = score + roll; loop = score < goal
```

```
    return score
```



Look familiar?